

## SCIENCE – UNIFYING STANDARDS

**THE NATURE OF SCIENCE**

- 1.0 **Research and Investigation:** Students understand that science is a way of learning about the natural world. They use scientific inquiry and develop ideas based on data collected from investigations they design.
- 2.0 **Communication:** Students understand that the universe can be described by principles derived through scientific inquiry. They effectively communicate their understanding of ideas developed in scientific investigation through a variety of media.
- 3.0 **Connections and Implications:** Students review the consequences of the process and products of scientific inquiry. They understand the role that scientific advances have had throughout history.

**EARTH SCIENCE**

- 1.0 **Characteristics of the Universe:** Students understand Earth-based and space-based astronomy reveals the structure, scale, and dynamic nature of the solar system, stars, galaxies, and the universe.
- 2.0 **The Dynamic Earth:** Students understand that the Earth is constantly changing and being shaped due to a variety of natural events, processes, and human activity. The Earth is a collection of interacting cycles, structures, and processes that can be described in terms of space, time, energy, and matter.

**LIFE SCIENCE**

- 1.0 **Diversity and Interdependence:** Students understand that living things are diverse and interdependent. They recognize the relationship between cooperation and competition among organisms in ecosystems.
- 2.0 **Cellular Structures and Functions:** Students understand that cells are the basic structures of all living systems. They understand the complementary relationship between the structure and function of cells, organs, organ systems, whole organisms, and ecosystems.
- 3.0 **Change and Evolution:** Students understand that living things grow, develop, change, and evolve through time, depending on environmental influences. They know that traits of species can change through generations and that instruction of traits is contained in the genetic material of organisms.

**PHYSICAL SCIENCE**

- 1.0 **Forces and Motion:** Students understand the nature of forces and the relationship between forces and motion. They recognize that the relationship is described by one set of laws. They understand that all matter is in motion and that motion changes as a result of forces between matter. They realize that these forces affect everyday life, and that the effects can be identified, measured, and predicted.
- 2.0 **Energy, Momentum and Transformation:** Students understand that when matter interacts with matter, energy and momentum can be transferred or distributed, and that energy may be transformed. When matter interacts the total amount of matter, energy, and momentum remain the same.
- 3.0 **Structure and Properties of Matter:** Students understand that all matter is made up of particles. They understand the relationship between the structure and properties of matter. They know that a finite number of basic elements combine in various ways which determine all properties, characteristics, and behaviors of matter.

**PHYSICAL SCIENCE**  
**Focus Goals Levels 9 – 12**

**1.0 Forces and Motion:** Students understand the nature of forces and the relationship between forces and motion. They recognize that the relationship is described by one set of laws. They understand that all matter is in motion and that motion changes as a result of forces between matter. They realize that these forces affect everyday life, and that the effects can be identified, measured, and predicted.

- 1.1 Describe the motion of objects.
- 1.2 Understand that changes of motion are governed by one set of laws.
- 1.3 Recognize what causes the forces between matter.
- 1.4 Know and explain that the nature of the interaction between objects is determined by the types of forces involved.

**2.0 Energy and momentum:** Students understand that when matter interacts with matter, energy and momentum can be transferred or distributed, and that energy may be transformed. When matter interacts the total amount of matter, energy, and momentum remain the same.

- 2.1 Show that when matter interacts with matter, energy and momentum are conserved during the interaction.
- 2.2 Understand and explain how atoms and molecules are perpetually in motion.
- 2.3 Know that in all processes, energy is distributed to the environment.
- 2.4 Describe the characteristics and behaviors of waves.
- 2.5 Know and explain how electric and magnetic phenomena are related.
- 2.6 Understand simple electrical circuits and their application to everyday life.

**3.0 Structure and Properties of Matter:** Students understand that all matter is made up of particles. They understand the relationship between the structure and properties of matter. They know that a finite number of basic elements combine in various ways which determine all properties, characteristics and behaviors of matter.

- 3.1 Distinguish the structure and functions of the atom.
- 3.2 Know that the periodic table is a system of organizing elements by similarities and trends.
- 3.3 Understand and describe how biological, chemical, and physical properties of matter result from the ability of atoms to form bonds.
- 3.4 Explain how the conservation of atoms in chemical reactions leads to the conservation of matter.
- 3.5 Know that the kinetic Molecular Theory describes the motion of atoms and molecules and explains the properties of gases.
- 3.6 Know that chemical reaction rates depend on factors that influence frequency of collision of reactant molecules.
- 3.7 Know that chemical equilibrium is a dynamic process at the molecular level.
- 3.8 Know that solutions are homogenous mixtures of two or more substances.
- 3.9 Know that acids, bases, and salts are three classes of compounds that form ions in water solutions.
- 3.10 Know that nuclear processes are those in which an atomic nucleus changes, including radioactive decay of naturally occurring and man-made isotopes, nuclear fission, and nuclear fusion.
- 3.11 Know that the bonding characteristics of carbon lead to many different molecules with varied sizes, shapes, and chemical properties, providing the biochemical basis of life.

**PHYSICAL SCIENCE**  
**Levels 9 – 12**

**1.0 Forces and Motion:** Students understand the nature of forces and the relationship between forces and motion. They recognize that the relationship is described by one set of laws. They understand that all matter is in motion and that motion changes as a result of forces between matter. They realize that these forces affect everyday life, and that the effects can be identified, measured, and predicted.

**1.1 Describe the motion of objects.**

- Understand that all matter is in motion. (p)
- Solve problems involving constant speed and average speed. (c1a)
- Understand that all motion depends on the frame of reference. (p)
- Recognize that there is no direct relationship between forces and motion. (p)
- \*Solve two-dimensional trajectory problems. (c1i)
- \*Solve problems in circular motion, using the formula for centripetal acceleration in the following form:  $a=v^2/r$ . (c1L-Phys)

**1.2 Understand that changes of motion are governed by one set of laws.**

- Recognize that when forces are balanced no acceleration occurs, and thus an object continues to move at a constant speed or stays at rest (Newton's First Law). (c1b)
- Apply the law  $F=ma$  to solve one-dimensional motion problems involving constant forces (Newton's Second Law). (c1c)
- Recognize that when one object exerts a force on a second object, the second object always exerts a force of equal magnitude and opposite direction. (Newton's Third Law). (c1d)
- Recognize that applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed (for example, the Earth's gravitational force causes a satellite in a circular orbit to change direction but not speed). (c1f)
- \*Recognize that Newton's Laws are not exact, but they do provide useful approximations unless an object is moving close to the speed of light or is small enough that the quantum effects become important. (c1h)
- Recognize that circular motion requires application of a force directed toward the center of the circle. (c1g)
- \*Resolve two-dimensional vectors into their components and calculate the magnitude and direction of a vector from its components. (c1j)
- \*Solve two-dimensional problems involving balanced forces (statics). (c1k)

**1.3 Recognize what causes the forces between matter.**

- Describe the universal law of gravitation and the effect of the gravitational force on an object at the surface of the Earth. (c1e)
- Demonstrate that friction is a force that may result whenever two surfaces are in contact, and that friction opposes motion. (c1p)
- \*Solve problems involving the forces between two electric charges at a distance (Coulomb's Law) or the forces between two masses at a distance (Universal gravitation). (c1m)

**1.4 Know and explain the nature of the interaction between objects is determined by the types of forces involved.**

- Recognize that electric forces acting within and between atoms are vastly stronger than gravitational forces. (p)
- Recognize that electric forces between oppositely charged electrons and protons hold atoms together and thus are involved in all chemical reactions. (p)
- Recognize that electric forces result from the interactions between charged objects like charges repel one another, opposite charges attract. (p)
- Demonstrate that different kinds of materials respond differently to electric forces in conducting materials such as metals, electrons flow easily, whereas in insulating materials such as glass, they can hardly flow. (p)
- \*Recognize that at very low temperatures, some materials become superconductors and offer no resistance to the flow of charges. (p)
- \*Know that magnetic forces are related to electric forces; moving electric charges produce magnetic forces and moving magnets produce electric forces this interplay of electric and magnetic forces manifests itself in electric motors, generators, and other technologies. (p)
- Recognize that charged particles are sources of electric fields and experience forces due to the electric fields from other charges. (c5e)
- \*Recognize that the force on a charged particle in an electric field is  $qE$ , where  $E$  is the electric field at the position of the particle and  $q$  is the charge of the particle. (c5k)
- \*Calculate the electric field resulting from a point charge. (c/5L-phys)
- \*Recognize that static electric fields have as their source some arrangement of electric charges. (c5m)
- \*Calculate and determine the direction of the force applied to a charge moving through a magnetic field using  $F = qvB \sin(\alpha)$  where  $\alpha$  is the angle between  $v$  and  $B$  ( $v$  and  $B$  are the magnitudes of vectors  $v$  and  $B$ , respectively), and students use the right hand rule to find the direction of this force. (c5n)

**2.0 Energy and momentum:** Students understand that when matter interacts with matter, energy and momentum can be transferred or distributed, and that energy may be transformed. When matter interacts the total amount of matter, energy, and momentum remain the same.

**2.1 Show that when matter interacts with matter, energy and momentum are conserved during the interaction.**

- Calculate changes in gravitational potential energy near the Earth using the formula (change in potential energy) =  $mgh$  (change in the elevation). (c2b)
- Calculate kinetic energy using the formula  $KE = (1/2)mv^2$ . (c2a)
- Recognize that momentum is a separately conserved quantity, different from kinetic energy. (c2e)
- Solve problems involving conservation of energy when forces between matter result in work being done. (p)
- Solve problems involving conservation of energy in simple systems such as falling objects. (c2c)
- Calculate momentum as product  $mv$ . (c2d)
- Solve problems involving elastic and inelastic collisions in one dimension using the principles of conservation of momentum energy. (c2g)

- Demonstrate that an unbalanced force on an object produces a change in its momentum. (c2f)
- \*Solve problems involving conservation of energy in simple systems with various sources of potential energy, such as capacitors and springs. (c2h, c5o)

## 2.2 Understand that atoms and molecules are perpetually in motion. (p)

- Recognize that thermal energy consists of random motion and the vibrations and rotations of atoms and molecules, and that the higher the temperature, the greater the atomic or molecular motion. (p)
- Describe temperature and heat flow in terms of the motion of molecules or atoms. (c7a-chem)
- Recognize that energy is released when a material condenses or freezes and absorbed when a material evaporates or melts. (c7c-chem)
- Solve problems involving heat and temperature changes, using known values of specific heat, and latent heat of phase change. (c2d-chem)
- Recognize that there are five states of matter; BEC, solid, liquid, gas, plasma; in order of increasing energy. (p)

## 2.3 Know that in all processes, energy is distributed to the environment.

- Recognize that heat and work are two forms of energy transfer between systems. (c3a)
- Recognize that chemical processes can either release (exothermic) or absorb (endothermic) thermal energy. (c7b-chem)
- Recognize that work done by a heat engine that is working in a cycle is the difference between the heat added to the engine at high temperature, and the heat removed at a lower temperature (First Law of Thermodynamics) and that this is an example of the law of conservation of energy. (c3b)
- Recognize that entropy is a quantity that measures the order or disorder of a system, and is larger for a more disordered system. (c3e)
- Recognize that most processes tend to decrease the order of a system over time, and energy levels are eventually distributed uniformly. (c3d)
- \*Recognize that the statement “entropy tends to increase” is a law of statistical probability that governs all closed systems (second Law of Thermodynamics). (c3f)
- \*Solve problems involving heat, work, and efficiency in a heat engine and recognize that all real engines have some heat flow out. (c3g)
- \*Apply Hess’s Law to calculate enthalpy change in a reaction. (c7e-chem)
- \*Use Gibb’s free energy equation to determine whether a reaction would be spontaneous. (c7f-chem)

## 2.4 Describe the characteristics and behaviors of waves.

- Recognize that waves carry energy from one place to another. (c4a)
- Identify transverse and longitudinal waves in mechanical media such as springs, ropes and the Earth (seismic waves). (c4b)
- Solve problems involving wavelength, frequency, and wave speed. (c4c)
- Recognize that sound is a longitudinal wave whose speed depends on the properties of the medium in which it propagates. (c4d)
- Relate radio waves, light, and X-rays to different wavelength bands in the spectrum of electromagnetic waves whose speed in vacuum is approximately  $3 \times 10^8$  m/s (186,000 miles/second). (c4e)
- Identify the characteristic properties of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization. (c4f)

**2.5 Know and explain how electric and magnetic phenomena are related.**

- Recognize that magnetic materials and electric currents (moving electric charges) are sources of magnetic fields and experience forces due to magnetic fields of other sources. (c5f)
- Determine the direction of a magnetic field produced by a current flowing in a straight wire or in a coil. (c5g)
- Recognize that changing magnetic fields produce electric fields, thereby inducing currents in nearby conductors. (c5h)
- \*Recognize that electric and magnetic fields contain energy and act as vector force fields. (c5j)

**2.6 Understand simple electrical circuits and their application to everyday life.**

- Predict the voltage or current in simple direct current electric circuits constructed from batteries, wires, resistors, and capacitors. (c5a)
- Solve problems involving Ohm's law. (c5b)
- Recognize that any resistive element in a DC circuit dissipates energy, which heats the resistor. (c5c)
- Calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula  $\text{Power} = IV$ , or  $I^2R$ , or  $V^2/R$  where  $I$  = current,  $R$  = resistance, and  $V$  = potential difference. (c5c)
- Recognize the properties of transistors and their role in electric circuits. (c5d)

**3.0 Structure and Properties of Matter:** Students understand that all matter is made up of particles. They understand the relationship between the structure and properties of matter. They know that a finite number of basic elements combine in various ways which determine all properties, characteristics and behaviors of matter.

**3.1 Distinguish the structure and functions of the atom.**

- Describe the historical development and experimental basis for atomic models. (p)
- Recognize that atoms are made of a positive nucleus surrounded by negative electrons. (p)
- Recognize that the nucleus, made of neutrons and protons, is much smaller in size than the atom but contains most of its mass. (c1e-chem)
- Recognize that neutrons have a mass that is nearly identical to that of protons, but have no electric charge. (p)
- Recognize that isotopes are atoms with the same number of protons but different number of neutrons. (p)
- \*Describe the experimental basis for Thomson's discovery of the electron, Rutherford's nuclear atom, Millikan's oil drop experiment, and Einstein's explanation of the photoelectric effect. (c/1h-chem)
- \*Describe the experimental basis for the development of the quantum theory of atomic structure and the historical importance of the Bohr model of the atom. (c1I-chem)
- \*Recognize that spectral lines are a result of transitions of electrons between energy levels. Their frequency is related to the energy spacing between levels using Planck's relationship ( $E=hn$ ). (c1j-chem)

### 3.2 Know that the periodic table is a system of organizing elements by similarities and trends.

- Recognize that the number of protons within an atom defines the element and is referred to as the atomic number. (p)
- Relate how to relate the position of an element in the Periodic Table to its atomic number and atomic mass. (c1a-chem)
- Recognize that elements are organized by increasing atomic number. (p)
- Use the Periodic Table to identify metals, semimetals, and nonmetals. (c1b-chem)
- Use the Periodic Table to identify alkali metals, alkali earth metals, transition metals, halogens, and noble gases. (c1c-chem)
- Use the Periodic Table to determine the number of electrons available for bonding. (c1d-chem)
- Make predictions based on the periodicity of the physical and chemical properties of the elements. (p)
- \*Use the Periodic Table to identify the lanthanides and actinides, and transactinide elements, and know that the transuranium elements were man made. (c1f-chem)
- \*Relate the position of an element in the periodic table to its quantum electron configuration, and reactivity with other elements in the table. (c1g-chem)

### 3.3 Understand and describe how biological, chemical, and physical properties of matter result from the ability of atoms to form bonds.

- Recognize that bonds form due to electrostatic forces between electrons and protons, and between atoms and molecules. (p)
- Use the position of atoms on the Periodic Table to draw Lewis dot structures. (c2e/chem)
- Recognize that atoms combine to form molecules by sharing electrons to form covalent bonds, transferring electrons to form ionic bonds, and de-localizing electrons to form metallic bonds. (c2a-chem)
- Recognize that chemical bonds between atoms in molecules such as H<sub>2</sub>, CH<sub>4</sub>, NH<sub>3</sub>, H<sub>2</sub>CCH<sub>2</sub>, N<sub>2</sub> Cl<sub>2</sub>, and many large biological molecules are covalent. (c2b-chem)
- Recognize that salt crystals such as NaCl are repeating patterns of positive and negative ions held together by electrostatic attraction. (c2c-chem)
- Recognize that there is a difference between intramolecular bonds and intermolecular bonds. (p)
- Recognize that in a liquid, the inter-molecular forces are weaker than in a solid, so that the molecules can move in a random pattern relative to one another. (c2d-chem)
- Recognize that the electron configuration of an atom, particularly the outermost electrons, determines how the atom can interact with other atoms. (p)
- \*Predict the shape of simple molecules and their polarity from Lewis dot structures. (c2f-chem)
- \*Relate electronegativity and ionization energy related to bond formation. (c2g-chem)
- \*Recognize that some solids and liquids are held together by Van der Waals forces, dipole-dipole interactions, and hydrogen bonding. Relate these forces to volatility and boiling / melting point temperatures. (c8h-chem)

### 3.4 Explain how the conservation of atoms in chemical reactions leads to the conservation of matter.

- Recognize that the quantity one mole is defined so that one mole of carbon 12 atoms has a mass of exactly 12 grams. (c3b-chem)
- Recognize that one mole equals 6.02x10<sup>23</sup> particles (atoms or molecules). (c3c-chem)

- Determine the molar mass of a molecule from its chemical formula and a table of atomic masses. (c3d-chem)
- Convert the mass of a molecular substance to moles, number of particles or volume of gas at standard temperature and pressure. (c3d-chem)
- Calculate the masses of reactants and products in a chemical reaction from the mass of one of the reactants or products, and the relevant atomic mass. (c3e-chem)
- Describe chemical reactions by writing balanced equations. (c3a-chem)
- \*Calculate percent yield in a chemical reaction. (c3f-chem)
- \*Identify reactions that involve oxidation and reduction and how to balance oxidation-reduction reactions. (c3g-chem)

### 3.5 **Know that the kinetic Molecular Theory describes the motion of atoms and molecules and explains the properties of gases.**

- Recognize that the random motion of molecules and their collisions with a surface create the observable pressure on that surface. (c4a-chem)
- Recognize that the random motion of molecules explains the diffusion of gases. (c4b-chem)
- Apply the gas laws to relations between the pressure, temperature, and volume of any amount of an ideal gas or any mixture of ideal gases. (c4c)
- Recognize that the values and meanings of standard temperature and pressure (STP). (c4d)
- Recognize that there is no temperature lower than 0 Kelvin. (c4f)
- Convert between Celsius and Kelvin temperature scales. (c4e)
- \*Recognize that the kinetic theory of gases relates the absolute temperature of a gas to the average kinetic energy of its molecules or atoms. (c4g-chem)
- \*Solve problems using the ideal gas law in the form  $PV=nRT$ . (c4h-chem)
- \*Apply Dalton's Law of Partial Pressures to describe the composition gases, and apply Graham's Law to describe diffusion of gases. (c4i-chem)

### 3.6 **Know that chemical reaction rates depend on factors that influence frequency of collision of reactant molecules.**

- Recognize that the rate of reaction is the decrease in concentration of reactants or the increase in concentration of products with respect to time. (c8a-chem)
- Recognize how reaction rates depend on such factors as concentration, temperature, pressure, and surface area. (c8b-chem)
- Recognize that energy is released when a material condenses or freezes and absorbed when a material evaporates or melts. (p)
- Recognize that the rate order of a reaction can be determined experimentally and possible reaction mechanisms can be predicted from the rate order. (p)
- Explain the role a catalyst plays in increasing the reaction rate. (c/8c-chem)
- \*Recognize the definition and role of activation energy in a chemical reaction. (c/8d-chem)

### 3.7 **Know that chemical equilibrium is a dynamic process at the molecular level.**

- Recognize that equilibrium is established when forward and reverse reaction rates are equal. (c9b-chem)
- Use Le Chatelier's Principle to predict the changes in concentration, temperature and pressure. (c/9a-chem)
- Solve problems using the equilibrium constant expression. (p)
- \*Write an equilibrium constant expression (Law of Mass Action). (c/9c-chem)

**3.8 Know that solutions are homogenous mixtures of two or more substances.**

- Define solute and solvent. (c6a-chem)
- Describe the dissolving process as a result of random molecular motion. (c6b-chem)
- Recognize that temperature, pressure, and surface area affect the dissolving process. (c6c-chem)
- Calculate the concentration of a solute in terms of grams per liter, molarity, parts per million and percent composition. (c6d-chem)
- \*Relate the molality of a solute in a solution to the solution depressed freezing point or elevated boiling point. (c6e-chem)
- \*Explain how molecules in solution are separated or purified by the methods of chromatography and distillation. (c6f-chem)

**3.9 Know that acids, bases, and salts are three classes of compounds that form ions in water solutions.**

- Observe properties of acids, bases, and salt solutions. (c5a-chem)
- Recognize that acids are hydrogen ion donating and bases are hydrogen ion accepting substances. (c5b-chem)
- Recognize that strong acids and bases fully dissociate and weak acids and bases partially dissociate. (c5c-chem)
- Use the pH scale to characterize acid and base solutions. (c5d-chem)
- \*Recognize Arrhenius, Bronsted-Lowry, and Lewis acid-base definitions. (c5e-chem)
- \*Calculate pH from the hydrogen ion concentration. (c/5f-chem)
- \*Use buffers to stabilize pH in acid-base reactions. (c/5g-chem)

**3.10 Know that nuclear processes are those in which an atomic nucleus changes, including radioactive decay of naturally occurring and man-made isotopes, nuclear fission, and nuclear fusion.**

- Recognize that protons and neutrons are held together by strong nuclear forces which are stronger than the electromagnetic repulsion between the protons. (c1a-chem)
- Recognize that the energy release per gram of material is much larger in nuclear fusion or fission than in chemical reactions: change in mass (calculated by  $E=mc^2$ ) is small but significant in nuclear reactions. (c11b-chem)
- Recognize that many naturally occurring isotopes of elements are radioactive, as are isotopes formed in nuclear reactions. (c11c-chem)
- Describe the three most common forms of radioactive decay (alpha, beta, and gamma) and how the nucleus changes in each type of decay. (c11d-chem)
- Recognize that alpha, beta, and gamma radiation produce different amounts and kinds of damage in matter and have different penetrations. (c11e-chem)
- \*Calculate the amount of radioactive substance remaining after an integral number of half-lives have passed. (c11f-chem)
- \*Recognize that protons and neutrons have substructure and consist of particles called quarks. (c11g-chem)

**3.11 Know that the bonding characteristics of carbon lead to many different molecules with varied sizes, shapes, and chemical properties, providing the biochemical basis of life.**

- Recognize that repetitive combinations of simple sub-units form large molecules (polymers) such as proteins, nucleic acids, and starch. (c10a-chem)
- Recognize that the bonding characteristics of carbon lead to a large variety of substances ranging from simple hydrocarbons to complex polymers and biological molecules. (c10b-chem)
- Recognize that amino acids are the building blocks of proteins. (c10c-chem)
- Describe the system for naming the ten simplest linear hydrocarbons and isomers containing single bonds, simple hydrocarbons with double and triple bonds, and simple molecules containing a benzene ring. (c10d-chem)
- \*Identify the functional groups, which form the basis of alcohol, ketones, ethers, amines, esters, aldehydes, and organic acids. (c10e-chem.)
- \*Describe the R-group structure of amino acids and how they combine to form the polypeptide backbone structure of proteins. (c10f-chem)